Final Report

Impact of Utility Cuts on Performance of Street Pavements

by

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PREFACE

The network of city streets represents one of the largest expenditures of any municipality. Road surface is a key component and proper construction and maintenance are essential to continued function. A utility cut, an opening made in the pavement by a utility company to repair existing utilities or to install new services, can cause premature deterioration of the cut repair and the pavement area beyond the cut, resulting in added repair cost. Although a number of studies have been conducted, there remain many uncertainties regarding the physical effects and true cost of utility cuts.

The purpose of this document is to review past studies and to describe the two techniques developed in this study for evaluating the condition of utility cuts and surrounding pavements. The first technique is based on an objective assessment which includes deflection measurements on Asphaltic Concrete or Macadam pavements and Finite Element Analysis of Portland Cement Concrete pavements. The second technique involves subjective methodologies based on visual observation of distress. Possible methods of pavement strengthening and their estimated costs are discussed. Additionally, cost models and procedures to assess the monetary impact are presented to aid municipalities in establishing guidelines for cost recovery.

This study was sponsored by the City of Cincinnati and by the American Public Works Association. It was conducted over a three-year period from 1991 into 1994 by the staff and students of the Civil and Environmental Engineering Department, Cincinnati Infrastructure Institute, University of Cincinnati, under the general supervision of Dr. Andrew Bodocsi. Principal investigators included Drs. A. Emin Aktan, Prahlad D. Pant, and Rajagopal Arudi.

IMPACT OF UTILITY CUTS ON PERFORMANCE
OF STREET PAVEMENTS

EXECUTIVE SUMMARY

ABSTRACT

Many utility cuts are made annually in city street pavements by utility companies to install or inspect utility services. Although the utility companies fill up the cuts and restore the pavement sections, often it is observed that the pavement section in and around the vicinity of such cuts fail at an accelerated pace. The resulting condition has a profound influence on pavement life, maintenance cost, aesthetics, and safety of motorists. This report presents the results of a study at the University of Cincinnati to assess the damage caused by the utility cuts on the pavements. The study provides procedures for establishing the extent of damage by deflection measurements. The distress manual and the rating index called Utility Cut Condition Index developed as a part of this study assists the city managers in the maintenance of utility cuts. The existing problems related to the management of utility cuts, the methodology of the study, and a summary of the results and their implications for implementation are presented. The results of the study are synthesized in a Windows based microcomputer tool called UCMS (Utility Cut Management System). Using the user input data, the software evaluates the condition of utility cuts, computes additional cost for maintenance in the event of poor restoration and presents a report on budget requirements to upgrade the condition of a group of cuts. At present, the software works as a stand alone model. With some effort, the software can be integrated into an existing Pavement Management System.

BACKGROUND

On city street pavements, very often utility companies dig open a section of a pavement in order to install or inspect utility services, and restore it in accordance with the existing guidelines and specifications. Such a location within a pavement section is termed a 'utility cut'.

In big cities, several thousands of cuts are made every year. The cities recover a fixed amount for each cut from utility companies in the form of a permit fee (APWA Annual Meetings Proceedings, 1991). The current fee structure is not based on scientific investigation of associated costs. Of late, there is a growing concern among cities to revise the existing cost recovery policy. Such an attempt should be supported by field tests and long-term monitoring of cut pavement performance.

Recognizing the need for a scientific, reliable and yet practical approach, the University of Cincinnati in association with the City of Cincinnati and the American Public Works Association, initiated a study with the following objectives:

(i) develop field techniques appropriate for the evaluation of utility cuts based on subjective assessment (visual inspection of distresses) and objective measurement of strength (deflection);

(ii) develop cost models and procedures to assess the monetary impact of utility cuts in order to establish guidelines for recovering costs; and

(iii) develop a management system to interact and coordinate between the various phases of cut evaluation and cost recovery.

CURRENT PROCEDURES TO RECOVER THE COST OF UTILITY CUTS

During recent years, many innovative techniques have been developed for rehabilitation of distressed pavement structures. Studies on cost effectiveness of various rehabilitation strategies, for pavements that have reached a particular stage of their functional and economical life, have created a new generation of civil engineering technologies. Unfortunately, none of these studies can be directly related to evaluate the impact of utility cuts on pavement performance. In the absence of specific guidelines for assessing the life and cost impact of utility cuts, cities have developed their own fee structure, based on the experience of engineers. The fee, termed as permit fee, recovers monies for administration and inspection of cuts. The utility is charged a fixed amount for every cut pavement and for every inspection. For instance, the City of Cincinnati charges about $80 per cut. A study by the Boston Department of the Public Works revealed that administrative costs have not been updated for many years, and the current cost allocation procedures are primitive (APWA Annual Meeting Proceedings, 1991). Similar situations exist in many other cities, which puts pressure on the local governments to revise the cost recovery policy.

AMERICAN PUBLIC WORKS ASSOCIATION'S EFFORTS

In view of the need for uniform and specific guidelines, the American Public Works Association (APWA) has prepared a draft report titled 'Recovering the Costs of Pavement Cuts - Opening and Restoration' (APWA Research Foundation, 1991). The draft report presents a review of various methods of opening and restoring pavements adopted by several cities, merits and demerits of each, and cites examples of added maintenance cost due to poor restoration. However, this report does not incorporate specific guidelines for evaluating the impact of cuts and establishing a cost recovery policy.

DEVELOPMENT OF FIELD EVALUATION TECHNIQUES

The study carried out at the University of Cincinnati examined several methods of evaluating impact of utility cuts on:

(i) Strength characteristics (deflection measurements using Dynaflect, FWD, Benkelman Beam) and

(ii) Surface characteristics (visual inspection).

The methodology adopted in this study is presented in the form of a flow chart in Fig. 1. Strength evaluation comprised of deflection measurements in and around the cuts in asphalt and concrete pavements. Initial survey of surface condition of cuts in concrete pavements revealed that there were no visible distresses and the cuts were in good condition. Hence, the visual condition survey was limited only to cuts in asphalt surfaced pavements.

Size of Cuts

The size of cuts to be evaluated is generally small in comparison with those of the surrounding pavements. Pavements are assumed to have infinite dimensions in the horizontal direction, hence the boundary influence will be ignored. On the other hand, cuts have a finite size, which will have a significant effect on the performance of the pavement in and around the cut. Therefore, identifying a representative size of cuts was important to plan the field evaluation studies.

To this end, a survey was carried out to determine the distribution of size of utility cuts on pavements in Cincinnati. The results indicated that the average size of the utility cuts is 5 feet by 4 feet.

Strength Tests

The results of the detailed studies indicated that the measurement of the deflection profile on asphalt pavements is not necessary for routine evaluation of cuts. Instead, one-point deflection measurements would be sufficient. Hence, the deflection measurement process has been simplified by using a Benkelman Beam, and measuring only the maximum deflection under a truck wheel load. However, it should be realized that, the measurement of deflection profile would give a more detailed assessment of the overall condition of a cut, when necessary.

The deflection tests were carried out in two phases. The first phase involved a comprehensive study around typical utility cuts to find the areal extent of pavement weakening, and the critical points for deflection measurement. The second phase involved routine measurement of deflections at the critical points, as identified in the

first phase. Deflection measurements were made at closer intervals near the cut and on a control point at a distance of 2.4m (8 feet) away from the edge of the cut. This control point assumed to be in a zone of no influence. The deflections measured in and around the cut, was utilized to establish the extent of influence. In all, 36 cuts were tested in the first phase. A statistical analysis of this data was made to establish the extent of area influenced by the cuts, based on the deflection values. The results indicated that the average extent of damage extends to 0.9m (3 feet) from the edges of the cut (Bodocsi, Arudi and Keiser, 1993). In addition, the maximum deflection at the center or the edge of the cut, whichever was higher, was compared with the deflection measured at the control point.

On cuts in concrete pavements, deflection measurements were made using a Falling Weight Deflectometer. A finite element model was developed to compute the stresses and strains in the concrete slabs at critical locations. The analytical study aimed at identifying critical locations of a cut within a slab. The results show that cuts in 9 inch thick slabs are generally not damaging, unless they are near the curb.

Distress Manual, Distress Surveys and Rating Index

A Distress Identification Manual for Utility Cuts (University of Cincinnati, Cincinnati Infrastructure Institute, 1991) was developed to familiarize the engineers and inspectors with possible distresses in and around utility cuts and provide guidelines for identifying the distresses and estimating their severity levels.

In all, 75 cuts on asphalt pavements were surveyed by a team of 15 engineers and highway maintenance inspectors. The engineers and inspectors were asked to fill out an Evaluation Form for each cut. The Evaluation Form (Fig. 2) was designed to extract information on the type and severity of distresses present in and around the cuts. The engineers and inspectors were also asked to recommend an action for maintenance. It was observed that with proper training, the information required in the Evaluation Form could be collected at each site in about 5 minutes.

Prior to the distress survey, the team of engineers and inspectors were trained for distress evaluation. As a training tool, the Delphi Method was used. This method assisted in reducing variations in the opinions among panel members by allowing them to reconsider their previous opinions based on the summary of opinions of all members in the panel. The information obtained from the distress survey was processed in an Artificial Neural Network (Pant et al., 1993) and a rating index called 'Utility Cut Condition Index' (UCCI) was developed.

COST ANALYSIS

The study indicated that the cuts made in concrete pavements in Cincinnati do conform to the strength requirements and do not need additional strengthening. However, the cuts in asphalt pavements were found to require additional strengthening. Based on the maximum deflections in and around the cuts and that at the control point, the required average overlay thickness was computed to bring the pavement up to its original strength. For the asphalt surface pavements, this was found to be 1.15 inch. For a cut with an average size of 5 ft. by 4 ft., the cost of this strengthening was found to be a minimum of $950. This cost included the expense of grinding off part of the old pavements, hauling of material and the cost of placing the new high-strength overlay. For the City of Cincinnati, where approximately 6000 cuts are made in asphalt pavements, the total yearly cost to be recovered could amount to $2,000,000. However, it should be pointed out that these figures are based on limited data and further work is necessary to refine the computations.

UTILITY CUT MANAGEMENT SYSTEM (UCMS)

The UCMS is a synthesis of field evaluation procedures, cost management, and policy issues related to maintenance of utility cuts. The goals of UCMS are:

(i)   To identify the method most useful for evaluating performance of utility cuts;
(ii)   To differentiate between the quality of restoration by different utilities/sub-contractors;
(iii) To generate a comprehensive database;
(iv)   To develop statistically calibrated models to predict future performance, life-cycle cost and monetary impact;
(v)   To address issues related to planning, investments and maintenance activities.

An MS-Windows based software (UCMS Ver. 1.0) has been developed for the implementation of UCMS.

Evaluating Maintenance Requirements

The deflection data is used in the computation of overlay thickness. If the deflection at any point within or near the cut is greater than the deflection at the control point, an overlay is recommended and the overlay thickness required for the excess deflection is computed by the Asphalt Institute Method. In the event that deflection data is not available, the recommendation on maintenance and rehabilitation action made by the engineers and inspectors during the distress survey based on the UCCI value is used.

The model considers labor, material and equipment costs to compute the total cost of a given M&R action. A facility has been provided to update the costs with the changing market prices. The program computes the total cost to upgrade a cut over its entire area plus an area of pavement influenced by the cut.

IMPLEMENTATION

Deflection measurements at or near the critical locations will be used as the criteria for estimating the extent of damage and the cost to be recovered. The rating index, UCCI, will serve as a management tool to identify the time at which remedial action is to be implemented. For instance, the deflection measurement may indicate a poor structural condition of the pavement at the time of measurement. However, the surface condition of the cut could still be acceptable, which may cause the engineers to defer any remedial action. But, if the strengthening of the pavement is deferred, a continual deterioration will take place with time and will require a thicker overlay in the future. Hence, the UCCI can be used to identify the time when a remedial action will be required.

The UCMS considers all important facets of damage assessment, cost recovery, maintenance program, consequences of deferred maintenance, and viable actions.

SUMMARY OF TASKS FOR MANAGEMENT SYSTEM

The utility cut management system, will comprise the following tasks, performed by a participating city:

1. Choose a random sample of typical utility cuts
2. Conduct a comprehensive study to establish the typical aerial extent of weakened pavement around cuts
3. Make deflection measurements on each selected cut at critical locations
4. Compute the overlay thickness required to bring the cut and the influenced area of pavement up to the strength of the unaffected original pavement
5. Compute the typical cost of overlay
6. Bill the utility companies for the cost determined and deposit the money in an escrow account
7. Visually inspect the sample cuts every other year. Assess their structural condition, determine UCCI and enter into the database
8. Use the management system to suggest the most appropriate repair action, time and the probable technical and economic consequence

CONCLUDING REMARKS

The performance characteristics of city street pavement with utility cuts widely differ from those of highway pavements. No specific studies have been carried out so far to evaluate the impact of utility cuts on the performance of pavements. However, it is generally observed that the pavement sections in and around a cut generally fail at an accelerated pace. The resulting condition will have an influence on (i) pavement life, (ii) pavement maintenance cost, (iii) vehicle operating cost, (iv) aesthetics, and (v) safety of motorists. Presently, to maintain the street pavements with cuts at the same level as the surrounding pavement sections, cities are recovering a fixed amount from the utility companies. In general, city officials believe that this cost recovery policy is not based on systematic methods of performance evaluation, and the amounts recovered in most cases, are grossly inadequate to maintain the pavements. Hence, two critical questions to be addressed are: (i) what is the extent of damage, and (ii) what is the appropriate cost to be recovered.

The utility cut management system developed in this study is based on a detailed investigation of the strength and performance characteristics of utility cuts. The field evaluation procedure comprises both objective measurement of deflections and subjective measurement of visual distresses. The deflection measurements assist in establishing the area of the pavement influenced by the cut and the cost to be recovered. The subjective evaluation of condition lead to the development of a rating index termed as Utility Cut Condition Index (UCCI). The UCCI is a valuable management tool for city managers to identify and prioritize candidate projects for maintenance. The management system for utility cuts considers all important facets of damage assessment, cost recovery, maintenance programs, and is designed so that the technology can be easily transferred to other cities facing similar problems.

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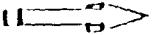
CINCINNATI INFRASTRUCTURE INSTITUTE

IMPACT OF UTILITY CUTS ON PERFORMANCE OF CITY STREET PAVEMENTS

Strength Evaluation →

Distress Survey →

Cost Data →

Management of Utility Cuts

→ Remedial Action

→ Maintenance Schedule

→ Maintenance Cost

Strength Evaluation

Asphalt Pavements

Experimental

Deflection

Choice of Instru.

36 Cuts

Critical Points

Deflection Measure

Summer · Winter

Seasonal Correction Factor

Temperature Correction Factor

Lateral Extent Damage

M & R Strategy

Remedial Action

Concrete Pavements

Analytical

Finite Element Method

Distress Survey

Distress Manual

75 Cuts

Delphi Survey

Neural Network

UCCI

Performance Models

Life Expectancy

Maintenance Schedule

Database

Maintenance $ $ $

Life Cycle Performance Models

Prep d by: _____ Date of Survey: _____

Location: _____ Time of Survey: _____

Surface Profile	very poor	poor	fair	good	excellent
(enter a number)	0 - 20	21 - 40	41 - 60	61 - 80	81 - 100
$\Longrightarrow$					

Distresses (Rate by severity. If different levels exist, rate by highest severity)	Cut			Vicinity			Any additional distress?	
	low	moderate	high	low	moderate	high		
Alligator Cracking								
Edge Cracking								
Transverse Cracking							Overall condition	very poor (0-20) poor (21-40) fair (41-60) good (61-80) excellent (81-100)
Potholes								
Rutting								
Ravelling & Weathering								
Cut-to-Adjacent Pavement Drop-off							Recommended action	do nothing surface treatment overlay reconstruct
Edge Separation								
Corner Breaks								

Additional Remarks:

ES Fig 2.

Evaluation forms for utility cuts

CHAPTER 1

INTRODUCTION

Background

Pavements in general rely on their continuity for strength, so when a utility cut is made in a pavement its strength will most likely decrease. This strength loss often results in increased deflections at or near the cut and, in time, various distresses may appear like cracks, potholes and ruts. Not only can the pavement lose strength, but the ride over the cut may become rough and the pavement surface may appear unsightly. User safety and vehicle damage become an issue. The result of such conditions is that the city may incur unforseen costs when it is forced to maintain the cuts or overlay streets before the scheduled time. Ideally, with proper restoration of cuts, these added costs may be reduced or even eliminated.

In large cities thousands of utility cuts are made annually in the road pavements. In the City of Cincinnati, for example, between 6,000 and 10,000 cuts are made each year. In Cincinnati, a standard, relatively small, fee is charged to the utility company when it makes a cut. This is known as a permit fee and is considered to cover administrative and inspection costs only. The restoration is assumed to be adequate and that it will require no further maintenance. There is an emerging recognition that there are added maintenance costs associated with utility cuts and that these costs may be substantial. Consequently, the adequacy of the permit fee system in Cincinnati and in other cities is under scrutiny. In many cases, fees have not been revised for some time nor have utility cuts been evaluated in view of the actual damage they cause. Clearly there is need to establish a realistic fee and to determine, on a rational basis, the true cost of utility cuts.

State of the Art

Shahin and Crovetti conducted a study in Burlington, Vermont on the effects of utility cuts on pavement performance, maintenance and rehabilitation costs [1.1]. This study described methods for structural testing and computations of additional rehabilitation costs associated with pavement cuts. The study investigated the average pavement life, with and without utility cuts. The analysis was based on a visual condition survey and structural testing using the Falling Weight Deflectometer (FWD), and investigated how these cuts affect the rehabilitation costs. The study calculated a life reduction factor of 1.72, as determined from their Pavement Condition Index (PCI) analysis and the overlay thickness requirements for 10 Equivalent Single Axle Loads (ESAL) per day. For pavements with utility cuts, this reduction factor translated to a $522,000 per year spending by Burlington in additional maintenance costs.

The Southern California Gas Company sponsored a study to analyze the findings of Shahin & Crovetti. The conclusions drawn by this study are summarized below:

a)   The life reduction factor of 1.72 is questionable because no justification was made for the choice of the critical PCI of 70 used in the study. A PCI of 70 borders on characterizing a pavement condition of between very good and good and is not a typical or standard value which agencies, institutions or governments use to determine when rehabilitation of a pavement is required.

b)   The method used by Shahin & Crovetti in the overlay design was the Asphalt Institute Method which specifies that the deflections be measured by the Benkelman Beam. However, they used the FWD to measure pavement deflections without correlating the deflections from the two devices.

c)   An unjustifiably high 80% of the Burlington's street systems was deemed in need of

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an overlay

d) The use of an overall 10 ESALs per day for all streets was not representative of actual conditions because residential, collector and arterial streets were all treated equally.

The American Public Works Association and the American Society of Civil Engineers published a joint report entitled "Accomodation of Utility Plant within the Rights-of-Way of Urban Streets and Highways" [1.2]. Also, the American Public Works Association and the University of Alabama Department of Civil Engineering for the Federal Highway Administration jointly published a guide entitled "Highway/Utility Guide" [1.3]. Both of these publications review right-of-way issues and permit procedures. They do not explore the issue of impact of utility cuts on pavement performance, or the cost-recovery policy based on such an evaluation.

The review of the Shahin and Crovetti report suggests that pavement performance at, and around, utility cuts has not been fully examined and that there is a need to take an in-depth systematic approach to this complex problem. With this in mind, the Cincinnati Infrastructure Institute of the University of Cincinnati, with the sponsorship of the City of Cincinnati and the American Public Works Association, initiated a three year effort to meet the need.

Study Objectives

The objectives of this study are:

1) Development of field methods and techniques, based on objective deflection measurements, for evaluating the structural condition of restored utility cuts and the surrounding pavement by:

   a) Objective deflection measurement techniques.

   b) Subjective visual distress detection and assessment techniques

2) Estimate the cost to the city of strengthening all weakened utility cuts and pavement around them.

The secondary objectives of this study are:

1) Development of a Finite Element Model for evaluating the effect of cuts on Portland Cement Concrete pavements.

2) Development of a Utility Cut Management System that synthesizes field evaluation procedures, cost management, and policy issues related to utility cuts in city street pavements.

Study Organization

This study deals with cuts in three major pavement types that are typical for the streets of the City of Cincinnati. They are Hot Mix Asphalt (AC), Macadam, and Portland Cement Concrete (PCC), mostly overlayed with AC. The AC and the Macadam pavement types together represent approximately 35% of the total pavement miles in the City of Cincinnati, while PCC pavements

represent about 35%. The remaining 30% is a composite type that is not included in this study.

A preliminary study was made to establish the average size of utility cuts in the City of Cincinnati that were larger than two feet by two feet. The average cut size was determined to be approximately five feet long by four feet wide.

Structural Evaluation of Cuts in AC and Macadam Pavements

This portion of the study consisted of objective strength measurements utilizing Benkelman Beam deflections. The goal was to make a determination of the lateral extent of damage caused to the pavements by the cuts, the severity of this damage, and the additional strengthening or overlay required to return the pavement to its original condition. The deflection testing program and findings for flexible pavements are described in Chapter 2 of this report.

Structural Evaluation of Cuts in PCC Pavements

Since the typical PCC pavement has the finite dimensions of twelve feet by fifteen feet and the cut can be in any arbitrary position within the extent of the slab, it was considered impractical to measure the true-life deflections in the typical slab for all configurations. Therefore, it was decided to model the slab with a cut by finite elements and find the critical stresses in the slab by a systematic application of a numerical method. Field data were used to calibrate the model. The findings associated with utility cuts in rigid pavements are presented in Chapter 3.

Repair Methods and Cost Analysis

Chapter 4 discusses the possible strengthening schemes applicable to Asphaltic Concrete and Macadam pavements. These schemes are aimed at restoring the original strength of the pavements at, or near, the cuts. The estimated cost of these schemes also is presented.

Distress Evaluation of All Pavements

This procedure utilized the Distress Identification Manual for Utility Cuts developed at the University of Cincinnati [1.4]. This Manual presents guidelines for the identification of all distresses in a cut and in its vicinity. The type and severity of these distresses are then used in computing the Utility Cut Condition Index (UCCI), which is a numerical rating for the condition of a cut. These indexes are stored in a utility cut database and may be used to monitor pavements with utility cuts, and to develop pavement performance prediction models. Visual distress evaluation is discussed in Chapter 5.

Management Model for Utility Cuts

In Chapter 6, a management model is presented to aid city officials in their decisions on maintenance, repair and strengthening of utility cuts and the pavement surrounding them.

Special Topics

Chapter 7 deals with special topics like multiple cuts in AC and Macadam pavements, comparison of Benkelman Beam and Dynaflect Test deflections, and Benkelman Beam and FWD Test deflections of AC and Macadam pavements.

Conclusions and recommendations are presented in Chapter 8.

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CHAPTER 2

STRENGTH EVALUATION

IN ASPHALTIC CONCRETE AND MACADAM PAVEMENTS

Introduction

Many cities have developed guidelines for utility cut opening and pavement restoration procedures. Still there are no standard procedures for the field evaluation of the quality of restoration and for assessing related costs in the event of a poor restoration. In this chapter, asphaltic concrete and macadam pavements are considered and a rational field technique is described for evaluating the structural condition of utility cuts and the surrounding pavement areas. The field technique is based on an objective measurement of strength, deflection. The testing instrument, test procedures and test siting conditions are described. Use of the deflection technique results in quantitatively defining the extent and severity of pavement damage and the required overlay necessary to restore the pavement to its original condition.

In Chapter 5, the description is given of an alternate method of analysis for assessing pavement damage caused by utility cuts. This is a subjective analysis using visual inspection of distress, from which a condition index, called the Utility Cut Condition Index, or UCCI, is determined.

Deflection Measurements:

Instrument, Procedure and Test Sites

The standard Benkelman Beam was used to measure rebound deflections of the flexible pavements when subjected to static loads. It is based on a lever arm and reference beam principle,

Figure 2.1. Soiltest Model HT-50 was used in this study. Specific features of this portable unit included: reference body beam, two-part probe beam, rear zero adjustment, battery operated vibrator, and a "Teleclock" dial gage of 0.001" accuracy. A five ton truck was used having a rear axle load of 18,000 pounds. The tires were dual 11.00" x 22.5" size, 12 ply and inflated to 70 psi. The deflection test involved measuring maximum rebound deflection under a truck wheel load as per the Canadian Good Roads Association Procedure [1]. The Benkelman Beam testing layout is illustrated in Figure 2.2.

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The deflection tests were carried out in two phases. The first phase involved a comprehensive study around utility cuts to find the areal extent of pavement weakening, and the critical points for deflection measurement. The second phase involved routine measurements of deflections at the critical points, as identified in the first phase. Figure 2.3 illustrates the location of deflection observation points. Deflection measurements were made at close intervals near the cut and on a control point at a distance of 8 feet away from the edge of the cut. This control point was assumed to be in a zone where the cut had no influence. The deflections measured in and around the cut were utilized to establish the extent of influence. In all, 36 cuts in asphalt and macadam pavements were tested. The results of the deflection tests at the 36 sites are presented in Appendix A. Figure 2.4 shows a typical plot of maximum one-point deflections in profile and the corresponding plan view of surface condition and test points in and around the cut.

Temperature and Seasonal Correction

The pavement surface temperature can have significant influence on the behavior of pavements. At higher temperatures, asphalt pavements are less stiff and deflect more. At cold temperatures, due to increase in stiffness, they deflect less. Hence, the Asphalt Institute [2] recommends that the

deflections measured be corrected for a standard temperature of 70 degrees F, using a standard adjustment factor, Figure 2.5. Table 2.1 is a compilation of deflections at one site that were adjusted for pavement surface temperature. Pavement deflections also vary with the season. Deflections will usually be larger during the rainy spring season or spring thaw. Deflection measurements made at any time of the year, therefore, should be corrected for the critical season using a seasonal correction factor. In order to do this, 12 cuts tested in summer were retested during the spring. The deflections were initially corrected for temperature and then a ratio of deflections during the two seasons was computed for each cut. A statistical analysis was carried out to determine the most representative value of the seasonal deflection correction factor. The results are summarized in Table 2.2. As seen, the average seasonal correction factor was found to be 1.26. All deflection values collected at times other than spring were multiplied by this factor after applying the appropriate temperature correction.

Lateral Extent of Damage

Using the deflection plots similar to Figure 2.4 for each cut tested, an analysis was made to estimate the average extent of pavement area affected by a cut. This was done by observing the deflection of points at and near the cut and comparing them to the deflection of the pavement at the control point (8 feet away from the cut). If the deflection at a point was found to be greater than the deflection at the control point, that point in the pavement was considered to be adversely affected by the cut. The aggregate of such points made up a zone of influence in and around the cut. The boundary of the zone was given by points where the deflection was equal to that of the control point. The width of the zone of influence around each cut was determined from its deflection plot. This varied with the size of the cut, traffic level and existing condition of the pavement. Of the 36 flexible pavement sites investigated, the average spread of damage beyond the cut edge was found

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to be 3 feet, Table 2.3. Thus the typical area of weakened pavement at and near a 4 foot by 5 foot cut, as illustrated in Figure 2.6, was found to be (4+6) x (5+6) = 110 square feet. To restore the strength of this area, or reduce its deflections to that of the control point, an overlay over the whole area of the weakened pavement may be applied.

Overlay Thickness Computations

The Asphalt Institute Method [3] was employed to compute the required overlay thicknesses needed to compensate for the damage caused by the utility cut. The key inputs for the overlay design at or around a cut were the maximum deflection, the reference deflection at the control point, and the traffic load in terms of the average Daily Traffic Number (DTN) over the design life of the overlay.

The Daily Traffic Number for which an overlay is designed can be found using the known values of the daily ESAL, the design life and traffic growth. Table 2.4 gives the initial daily ESAL for the streets where a traffic count was made.

The City of Cincinnati historically has used the following guidelines for the estimated design life of major rehabilitation on city streets.

Roadway Classification	Design Life (years)
Arterial	15
Secondary	20
Residential	30

In computing the DTN, the city uses a growth factor of 2% on the arterial and secondary streets, but no growth factor is applied to residential streets. However, note that just five years ago

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the ESAL's nearly doubled on residential streets with the institution of Cincinnati's recycling program.

The overlay thickness can be calculated by using Figure 2.7, the maximum deflection and the control point deflection. Using this figure, the overlay thickness was determined for both maximum deflection and control point deflection. This was done for both points by entering the figure with the deflection value, moving vertically until the curve with the appropriate DTN value was reached and then horizontally to read off the required overlay thickness The additional overlay required was the difference between the two calculated overlays.

Overlay Thickness Computations - Special Case

There was a special group of cuts that had to be handled differently. Around these cuts damage (excess deflection) was evident, but the ESAL's were small and Figure 2.7 indicated that no overlay was required for the pavement. However, since the City's pavement was measurably damaged, an overlay should be required to restore the pavement to its original strength regardless of traffic. This case was handled using an artifically inflated threshold DTN defined as one which would not require any overlay at the control point (8 feet away from the cut), but would necessitate an overlay at the point of maximum deflection at or near the cut. The overlay thickness for such a cut (or its surrounding pavement) was obtained from the AI Chart (Figure 2.7) for this threshold DTN.

For each cut, Table 2.5 shows the maximum deflection, the reference control point deflection, and the required overlay thickness associated with these deflections. The range of required overlay thicknesses varied from 0 to 6.0 inches. The average overlay thickness required to restore the pavement to its pre-utility cut strength was found to be 1.75 inches.

Analysis and Discussion

Table 2.6, the Summary Table, includes the age of each pavement and cut, the required additional overlay thickness, and the lateral extent of damage for each cut tested during this investigation. This table shows that utility cuts made in flexible pavements weaken and eventually damage the surrounding pavement. Table 2.6 also lists Utility Cut Condition Index (UCCI) values for the 36 sites. These values were determined using subjective techniques and the methodology is described in detail in Chapter 5, DISTRESS SURVEY. From the cuts physically tested, the extent of lateral damage varies from 0 to 6 feet, with an average of 3 feet. Table 2.6 shows the cuts categorized according to pavement type and traffic level, asphalt pavement from high to low traffic

followed by macadam pavement from high to low traffic. It also illustrates that, based on the limited number of tests in this study, no direct correlation can be shown between extent of pavement damage and pavement type, nor between pavement damage and traffic level.

Based on objective evaluations, thirty (30) of the thirty-six (36) cuts tested showed that the pavement surrounding the cuts had weakened to some degree, between one (1) and six (6) feet in lateral extent.. That is, approximately 80% of the cuts tested showed damage. The remaining six (7) cuts exhibited no apparent damage to the surrounding pavement. Age of cut may be a factor. Four of the seven cuts were between 1 and 2 years old, while two were 7 and 8 years old, respectively. The age of the remaining cut was unknown. This suggests that, in most cases, it may take several years for the damage to become evident.

The apparent individuality of the damage extent also is reflected in the results of the overlay design where the required thickness ranges from 0 to 6.0 inches. The overlay thicknesses appear to be somewhat related to the condition of the cut, (UCCI), but appear to be independent of the lateral extent of damage, Table 2.6.

Each case was evaluated independently and based solely on the maximum deflection and how it relates to the reference deflection. Generally, any cut which exhibits weakness across the cut or in the pavement in close proximity to the cut, will require an overlay to restore a consistent strength in the pavement. However, it is possible to require an overlay while having the lateral extent of damage equal zero (0). This situation could occur when the repair is weak, but the repair has not yet affected the surrounding pavement. In this case an overlay only directly over the cut is needed. Conversely, the case of a strong cut repair could also require an overlay. This case occurs where the strength of the repair may be equal to, or greater than, the strength of the reference

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section, however, weakening is shown in the pavement adjacent to the cut. In a case such as this the weakening may have occurred during the time that the cut was open and the subgrade weakened as a result of lateral creep or slumping of the sides of the excavation during an extended repair process.

Conclusions

The study carried out at the University of Cincinnati resulted in the development of an objective evaluation technique to assess the impact of utility cuts on surrounding flexible pavements. The study demonstrated that the Benkelman Beam can be used for the strength evaluation of flexible pavements at utility cuts and to determine the lateral extent of area affected by a cut. The average lateral extent of damage was found to be 3 feet, and the average overlay thickness required to restore the pavement to its pre-utility cut strength was found to be 1.75 inches.

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2.2.   The Asphalt Institute "Asphalt Overlays and Pavement Rehabilitation", Manual Series,
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2.1.   "AASHTO Guide for Design of Pavement Structures", American Association of State
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2.2.   Finn, N. F. and C. L. Monismith, "Asphalt Overlay Design Procedures", NCHRP
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2.3.   Shahin, M. Y. and J. A. Crovetti, 1986. "Effects of Utility Cut Patching on Pavement
        Performance and Rehabilitation Costs", Transportation Research Record.

TABLE 2.1. Typical Measured and Computed Deflections at a Site

TITLE: UCMACOBS2081-1

Point No	Intermediate Deflection (1/1000 in)	Final Deflection (1/1000 in)	Ave Interm Deflection (1/1000 in)	Ave Final Deflection (1/1000 in)	Corrected Deflection (in)	Temp Corrected Deflection (Caut = 0.03)	Seasonal Correction	Final True Deflection
1	88 / 87	97 / 89	185	188	0.0227	0.0211	1.00	0.021
2	158 / 140	162 / 148	298	311	0.0345	0.0321	1.00	0.032
3	182 / 188	183 / 178	328	358	0.0447	0.0418	1.00	0.042
4	128 / 122	131 / 131	248	282	0.0302	0.0281	1.00	0.028
5	108 / 111	111 / 121	218	232	0.0268	0.0250	1.00	0.025
6	101 / 101	108 / 110	202	218	0.0264	0.0245	1.00	0.025
7	100 / 102	105 / 113	202	218	0.0264	0.0245	1.00	0.025
8	82 / 104	101 / 112	198	213	0.0261	0.0243	1.00	0.024
9	100 / 102	107 / 108	202	218	0.0258	0.0238	1.00	0.024

TABLE 2.2 Seasonal Correction Coefficient

Corrected Spring Deflection (in.)	Corrected Non-spring Deflection (in.)	Deflection Ratio	Individual Cut Mean	Seasonal Correction
0.0150	0.0205	1.367		
0.0432	0.0486	1.125	1.317	
0.0327	0.0477	1.459		
0.0136	0.0170	1.250		
0.0212	0.0406	1.915	1.559	
0.0250	0.0378	1.512		
0.0285	0.0458	1.607		
0.0323	0.0371	1.149	1.301	
0.0292	0.0335	1.147		
0.0812	0.0831	1.023		
0.0740	0.0721	0.974	1.021	
0.0635	0.0676	1.065		
0.0195	0.0262	1.344		
0.0918	0.1031	1.123	1.219	
0.0736	0.0877	1.192		1.259
0.0162	0.0192	1.185		
0.0382	0.0351	0.919	1.006	
0.0389	0.0355	0.913		
0.0114	0.0180	1.579		
0.0140	0.0134	0.957	1.175	
0.0095	0.0094	0.989		
0.0372	0.0480	1.290		
0.0599	0.0847	1.414	1.375	
0.0526	0.0747	1.420		
0.0168	0.0172	1.024		
0.0253	0.0315	1.245	1.134	
0.0377	0.0427	1.133		
0.0173	0.0280	1.618		
0.0718	0.1091	1.519	1.485	
0.0724	0.0954	1.318		

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TABLE 2.3. Lateral Extent of Damage from Edge of Cut

Utility Cut No.	Extent of Influence	Traffic Average	Pavement Average	Final Average
UCASP7&PINT-1	4			
UCASPCLI3217-1	-			
UCASPCLIHUC-1	2			
UCASPEMC169-1	6			
UCASPEMC173-1	6			
UCASPEMC659-1	2	3.33		
UCASP8TH304N-1	3			
UCASP8TH304S-1	3			
UCASPFAR1720-1	-			
UCASPLIN859-1	2			
UCASPSTA2641-1	4			
UCASPVPW2229-1	1	2.17		
UCASPFFD3054-1	3			
UCASPPAV942-1	-			
UCASPPAV949-1	6			
UCASPPRK2324-1	3			
UCASPPRK2378-1	4			
UCASPROC1005-1	4	3.33	2.94	
UCMACBEK3241-1	4			
UCMACBEK3333-1	4			
UCMACBEK3411-1	-			
UCMACEDW3642-1	4			
UCMACEDW3821-1	1			
UCMACOBS2728-1	4	2.83		
UCMACLAF402-1	6			
UCMACMCA533-1	-			
UCMACOBS2881-1	2			
UCMACOBS3044-1	2			
UCMACOBS3060-1	4			
UCMACWTF3332-1	3	2.83		
UCMACDUN3422-1	4			
UCMACGRA458-1	-			
UCMACMON3431-1	6			
UCMACMON3579-1	-			
UCMACPUR426-1	6			2.97
UCMACPUR554-1	4	3.33	3.00	(3.00)

TABLE 2.4. Traffic Count Results

Addresses	Daily bus Sched.	Big Trucks			Trucks			Big Buses			Mini Buses			Daily ESAL/Lane
		A	B	C	A	B	C	A	B	˙C	A	B	C	
304 8th St.	138	1	4	1	17	8	9	9	8	10	--	--	--	476
Clifton Ave.	96	0	1	--	8	6	--	4	5	--	16	16	--	601
169 E. McMillan	132	3	1	0	27	22	14	14	10	12	3	9	6	523
859 Lincoln	43	0	0	0	3	4	2	6	2	3	1	0	1	343
3241/3333 Beekman	49	2	4	4	20	35	24	8	4	5	2	1	1	532
3411 Beekman	49	1	5	3	22	29	21	5	3	3	2	1	0	435
Stanton	0	0	1	1	1	1	2	1	0	0	1	0	2	41
2720 Observatory	30	0	2	1	16	18	12	2	2	6	0	0	1	312
2881 Observatory	10	0	0	0	8	6	2	0	0	2	0	0	1	69
3060 Observatory	10	0	0	0	9	8	3	0	0	1	0	0	0	43
3642 Edwards	32	0	0	1	7	12	11	2	2	3	2	3	0	253
3821 Edwards	84	4	0	3	9	3	14	3	2	2	0	2	1	407
7th and Plum	210	0	0	0	25	23	14	17	11	20	2	2	0	784

Legend:
A: 8:00AM -- 9:00AM
B: 10:00AM -- 11:00AM
C: 3:00PM -- 4:00PM

Date : October 1992

TABLE 2.5. Required Overlay Thickness

Utility Cut	Maximum Deflection (in)	Reference Deflection (in)	Overlay Thickness (in)
UCASP7&PINT-1	0.064	0.045	1.50
UCASPCLI3217-1	0.039	0.039	-
UCASPCLIHUC-1	0.023	0.012	5.00
UCASPEMC169-1	0.048	0.045	0.50
UCASPEMC173-1	0.049	0.020	4.00
UCASPEMC659-1	0.059	0.028	3.50
UCASP8TH304N-1	0.051	0.035	2.00
UCASP8TH304S-1	0.036	0.028	2.00
UCASPFAR1720-1	0.041	0.041	-
UCASPLIN859-1	0.161	0.087	3.50
UCASPSTA2641-1	0.109	0.094	1.00
UCASPVPW2229-1	0.074	0.059	2.00
UCASPFFD3054-1	0.050	0.047	1.00
UCASPPAV942-1	0.103	0.117	-
UCASPPAV949-1	0.095	0.030	5.50
UCASPPRK2324-1	0.082	0.054	2.00
UCASPPRK2378-1	0.040	0.031	2.00
UCASPROC1005-1	0.140	0.119	1.00
UCMACBEK3241-1	0.057	0.052	0.50
UCMACBEK3333-1	0.091	0.073	1.00
UCMACBEK3411-1	0.039	0.030	1.50
UCMACEDW3642-1	0.050	0.047	0.50
UCMACEDW3821-1	0.139	0.119	1.00
UCMACOBS2728-1	0.040	0.030	2.00
UCMACLAF402-1	0.062	0.021	6.00
UCMACMCAS33-1	0.062	0.078	-
UCMACOBS2881-1	0.042	0.024	0.50
UCMACOBS3044-1	0.051	0.048	0.50
UCMACOBS3060-1	0.058	0.042	1.50
UCMACWTF3332-1	0.039	0.032	2.00
UCMACDUN3422-1	0.147	0.130	1.00
UCMACGRA458-1	0.113	0.076	2.00
UCMACMON3431-1	0.130	0.111	1.00
UCMACMON3579-1	0.076	0.078	-
UCMACPUR426-1	0.109	0.079	1.50
UCMACPUR554-1	0.127	0.085	2.00
AVERAGE			1.69 (1.75)

NOTE 1 :- Overlay thickness is needed over cut only.

TABLE 2.6. Summary Table

Utility Cut	Age of Pavement (yrs)	Age of Cut (yr)	UCCI	ESAL (in '000)	Lateral Extent of Damage (ft)	Overlay Thickness (in)
UCASP7&PINT-1	16	1	39	4292	4	1.50
UCASPCLI3217-1	3	1	80	3290	-	-
UCASPCLIHUC-1	3	1	82	See *	2	5.00
UCASPEMC169-1	20	4	71	2863	6	0.50
UCASPEMC173-1	20	12	23	2863	6	4.00
UCASPEMC659-1	20	12	42	2863	2	3.50
UCASP8TH304N-1	14	3	54	2606	3	2.00
UCASP8TH304S-1	14	3	--	2606	3	2.00
UCASPFAR1720-1	14	2	--	See *	-	-
UCASPLIN859-1	8	1	51	2504	2	3.50
UCASPSTA2641-1	--	4	71	299	4	1.00
UCASPVPW2229-1	12	2	79	See *	1	2.00
UCASPFFD3054-1	14	2	--	See *	3	1.00
UCASPPAV942-1	14	7	47	"	-	-
UCASPPAV949-1	14	8	48	"	6	5.50
UCASPPRK2324-1	13	2	79	"	3	2.00
UCASPPRK2378-1	13	2	86	"	4	2.00
UCASPROC1005-1	13	10	--	"	4	1.00
UCMACBEK3241-1	15	2	72	2913	4	0.50
UCMACBEK3333-1	15	3	45	2913	4	1.00
UCMACBEK3411-1	15	8	46	2382	-	1.50
UCMACEDW3642-1	18	10	80	1385	4	0.50
UCMACEDW3821-1	--	6	17	2666	1	1.00
UCMACOBS2728-1	14	--	53	1708	4	2.00
UCMACLAF402-1	2	1	--	See *	6	6.00
UCMACMCA533-1	13	2	--	"	-	-
UCMACOBS2881-1	14	11	40	504	2	0.50
UCMACOBS3044-1	14	13	60	See *	2	0.50
UCMACOBS3060-1	14	5	82	314	4	1.50
UCMACWTF3332-1	14	5	--	See *	3	2.00
UCMACDUN3422-1	6	7	69	See *	4	1.00
UCMACGRA458-1	11	--	84	"	-	2.00
UCMACMON3431-1	14	8	77	"	6	1.00
UCMACMON3579-1	5	1	84	"	-	-
UCMACPUR426-1	9	9	85	"	6	1.50
UCMACPUR554-1	9	2	82	"	4	2.00
AVERAGE					2.97 (3.00)	1.69 (1.75)

NOTE * : ESAL's not available. Overlay thickness was calculated
to bring the strength of the damaged pavement back to
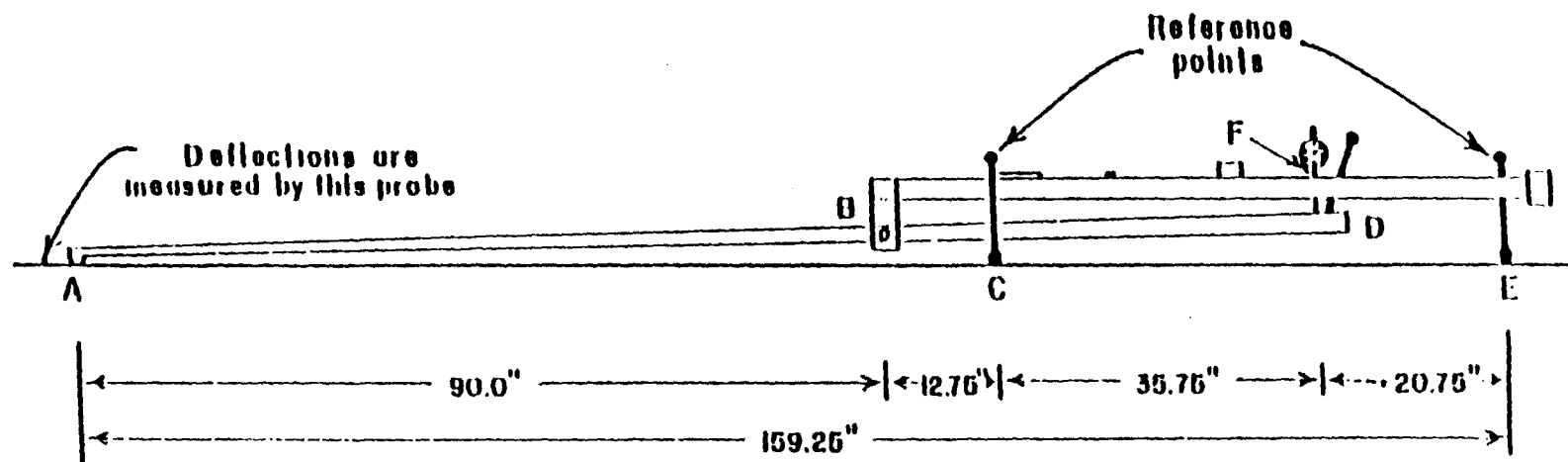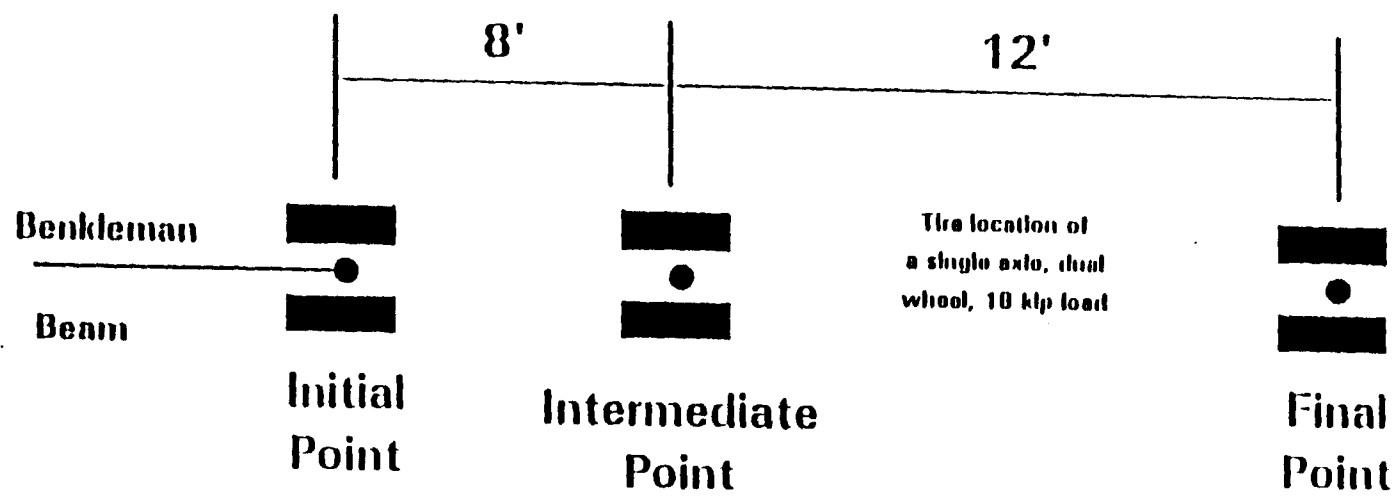that of the control point.
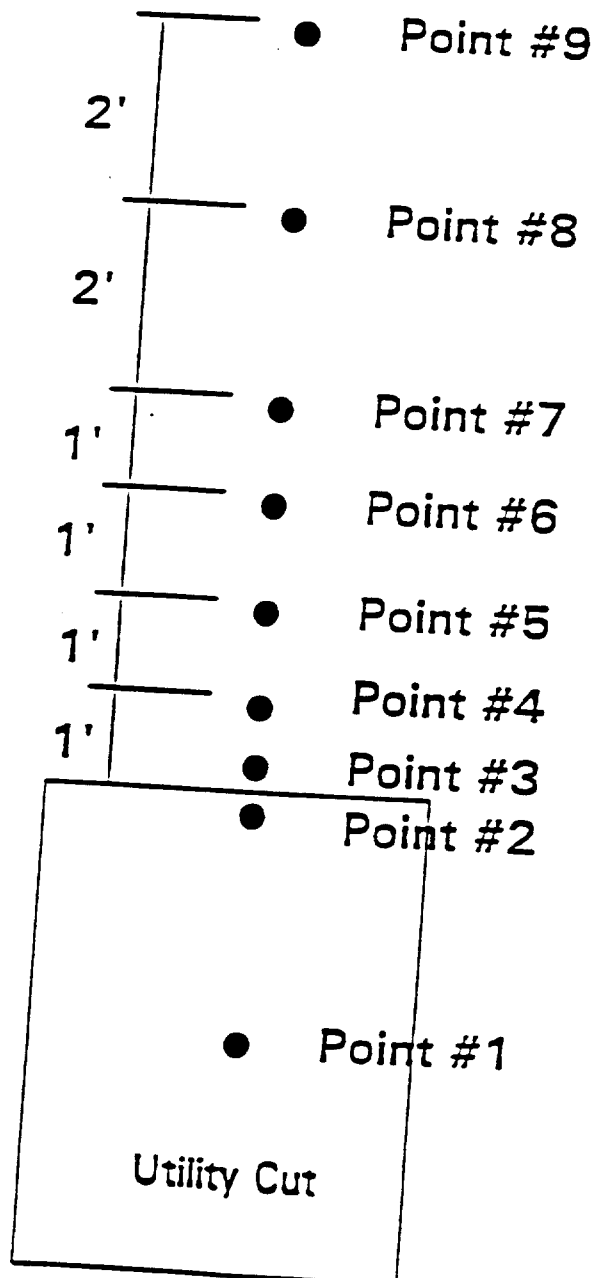
FIG. 2.1. Benkelman Beam

Benkleman

Beam

Initial
Point

Intermediate
Point

Tire location of
a single axle, dual
wheel, 18 kip load

Final
Point

8'   12'

FIG. 2.2. Benkelman Beam Testing Layout

Direction of Flow

● Point #9

2'

● Point #8

2'

● Point #7

1'

● Point #6

1'

● Point #5

1'

● Point #4

1'

● Point #3

● Point #2

● Point #1

Utility Cut

FIG. 2.3. Location of Deflection Observation Points

DISTANCE (ft.)

(a) DEFLECTIONS

CURB

10'
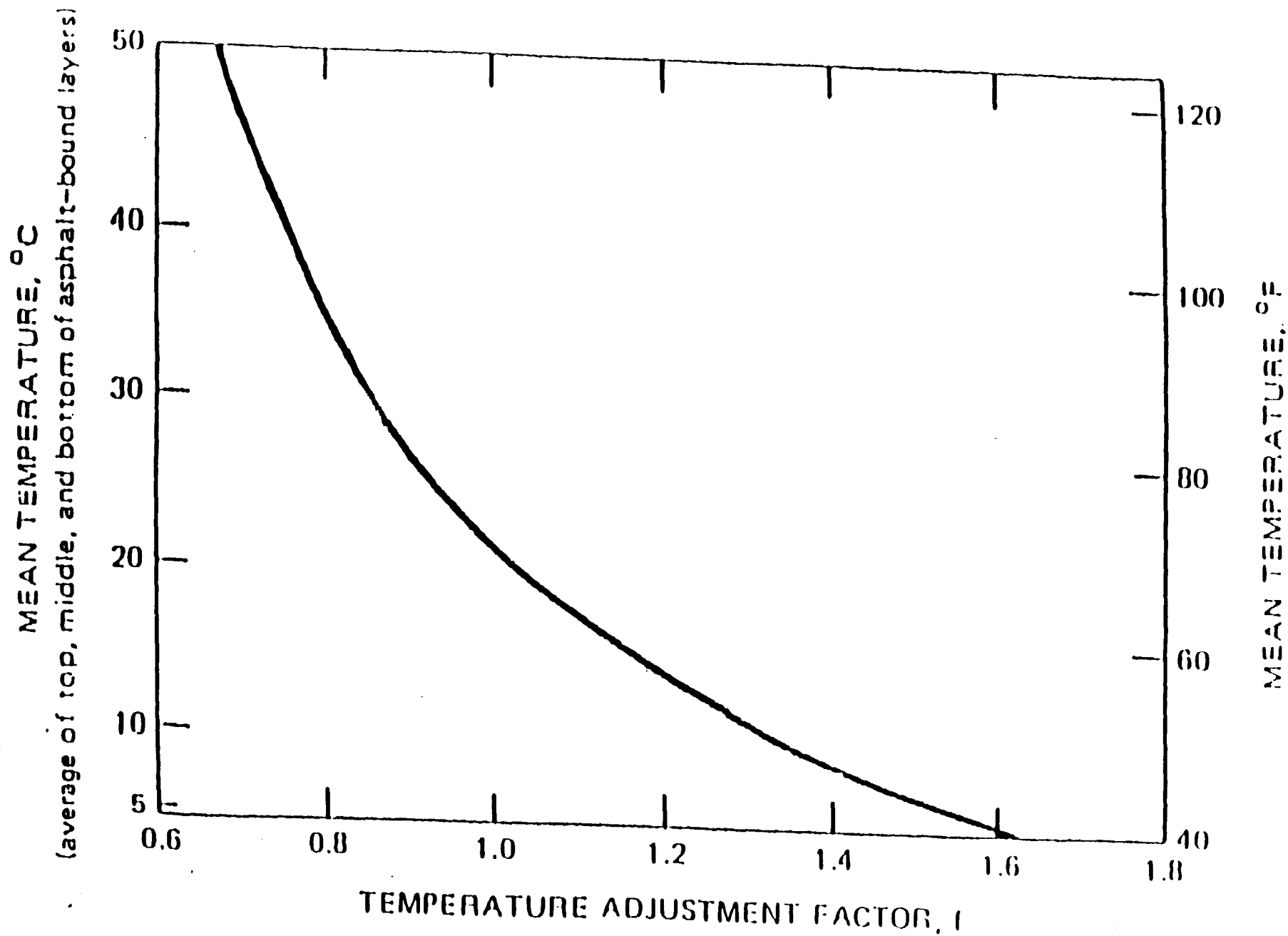
PATCH

72"

42"
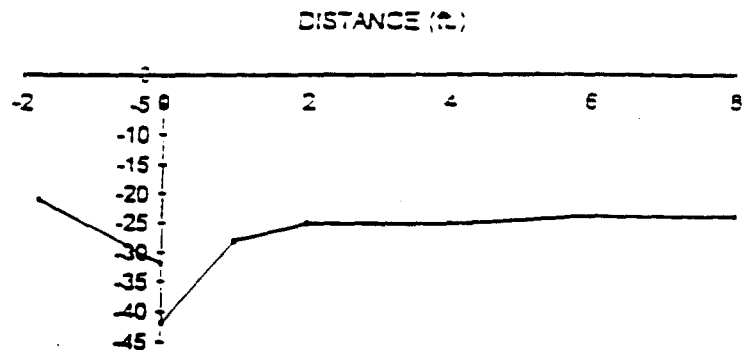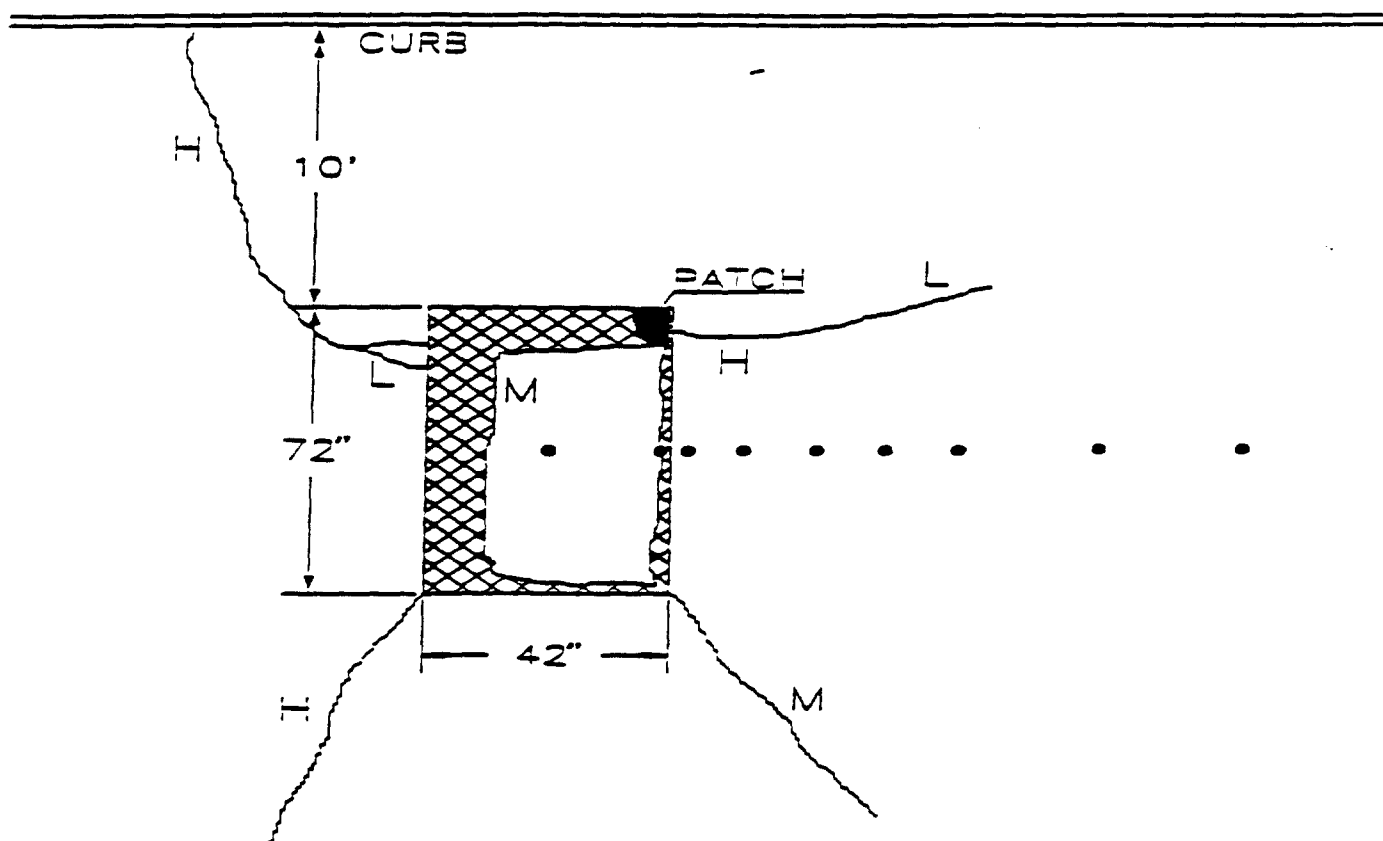
(b) PLAN VIEW

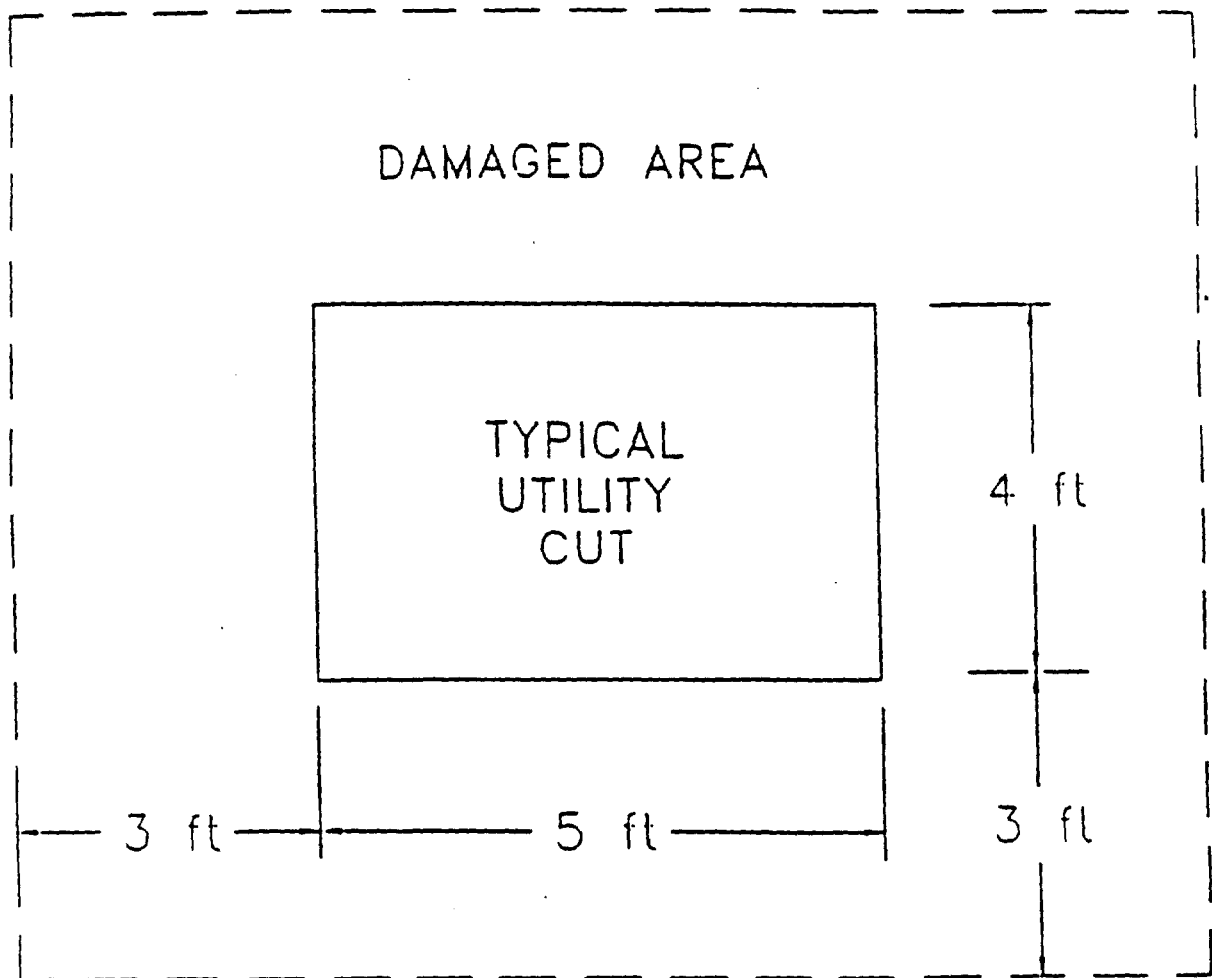FIG. 2.4. Plot of Deflections and Plan View at a Typical Cut

FIG. 2.5. Temperature Adjustment Factors for Benkelman Beam Deflections
(From the Asphalt Institute)
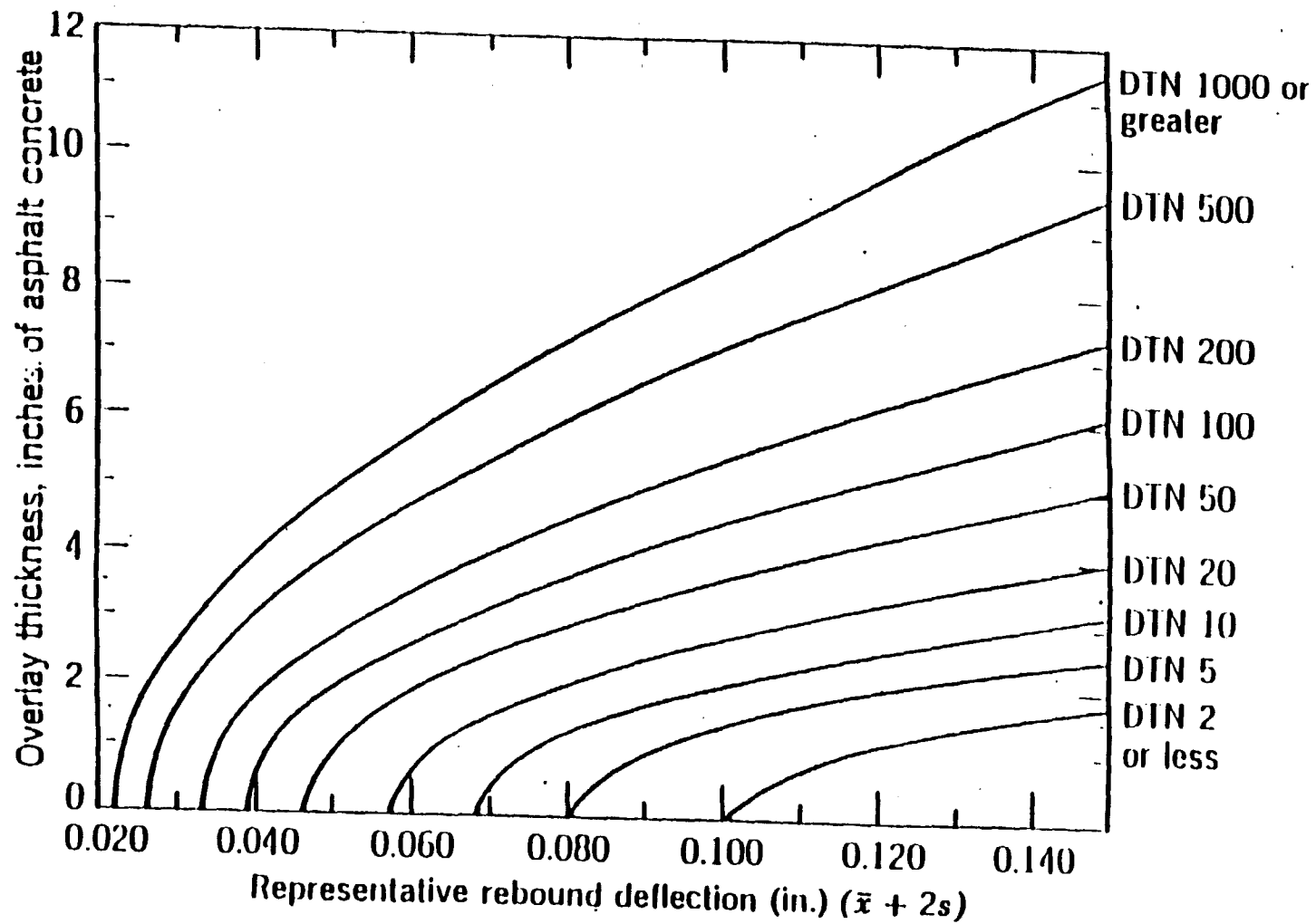
FIG. 2.6. Lateral Extent of Damage

FIG. 2.7. Asphalt Concrete Overlay Thickness Required to Reduce Pavement Deflection from a Measured to a Design Deflection Value (From the Asphalt Institute)